CS M151B Homework 1

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1.6 [20] <§1.6> Consider two different implementations of the same instruction set architecture. The instructions can be divided into four classes according to their CPI (class A, B, C, and D). P1 with a clock rate of 2.5 GHz and CPIs of 1, 2, 3, and 3, and P2 with a clock rate of 3 GHz and CPIs of 2, 2, 2, and 2.

Given a program with a dynamic instruction count of 1.0E6 instructions divided into classes as follows: 10% class A, 20% class B, 50% class C, and 20% class D, which implementation is faster?

a. What is the global CPI for each implementation?

b. Find the clock cycles required in both cases.

a. $CPI_1 = 0.1(1) + 0.2(2) + 0.5(3) + 0.2(3) = 2.6$

$CPI_2 = 0.1(2) + 0.2(2) + 0.5(2) + 0.2(2) = 2$

$\boxed{CPI_1 = 2.6, \ CPI_2 = 2}$

b. Process 1: 2.6×10^6 clock cycles

Process 2: 2×10^6 clock cycles

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1.5 [4] <§1.6> Consider three different processors P1, P2, and P3 executing the same instruction set. P1 has a 3 GHz clock rate and a CPI of 1.5. P2 has a 2.5 GHz clock rate and a CPI of 1.0. P3 has a 4.0 GHz clock rate and has a CPI of 2.2.

a. Which processor has the highest performance expressed in instructions per second?

b. If the processors each execute a program in 10 seconds, find the number of cycles and the number of instructions.

c. We are trying to reduce the execution time by 30% but this leads to an increase of 20% in the CPI. What clock rate should we have to get this time reduction?

a. P1: $\frac{1}{1.5} \frac{\text{instr}}{\text{cycle}} \times \frac{3 \times 10^9 \text{ cycles}}{\text{sec}} = 2 \times 10^9 \text{ instr} / \text{sec}$

P2: $\frac{1}{1.0} \frac{\text{instr}}{\text{cycle}} \times \frac{2.5 \times 10^9 \text{ cycles}}{\text{sec}} = 2.5 \times 10^9 \frac{\text{instr}}{\text{sec}}$

P3: $\frac{1}{2.2} \frac{\text{instr}}{\text{cycle}} \times \frac{4 \times 10^9 \text{ cycles}}{\text{sec}} = 1.81 \times 10^9 \frac{\text{instr}}{\text{sec}}$

$\boxed{\text{proccess 2}}$

b. P1: cycles $= 3 \times 10^9$ cycles/sec $\times 10$ sec $= \boxed{3 \times 10^{10} \text{ cycles}}$

instr $= 2 \times 10^9$ instr/sec $\times 10$ sec $= \boxed{2 \times 10^{10} \text{ instr.}}$

P2: cycles $= 2.5 \times 10^9$ cycles/sec $\times 10$ sec $= \boxed{2.5 \times 10^{11} \text{ cycles}}$

instr $= 2.5 \times 10^9$ instr/sec $\times 10$ sec $= \boxed{2.5 \times 10^{11} \text{ instr}}$

P3: cycles $= 4 \times 10^9$ cycles/sec $\times 10$ sec $= \boxed{4 \times 10^{11} \text{ cycles}}$

instr $= 1.8 \times 10^9$ instr/sec $\times 10$ sec $= \boxed{1.8 \times 10^{10} \text{ instr.}}$

c. $ET_0 = IC_0 \times CPI_0 \times CT_0$

$ET_1 = 0.7 ET_0$

$CPI_1 = 1.2 CPI_0$

$IC_1 = IC_0$

$ET_1 = IC_1 \times CPI_1 \times CT_1$

$0.70 ET_0 = IC_0 \times 1.20 CPI_0 \times CT_1$

$\Rightarrow 0.70 (IC_0 \times CPI_0 \times CT_0) = IC_0 \times 1.20 CPI_0 \times CT_1$

$0.70 CT_0 = 1.2 CT_1$

$CT_1 = \frac{0.7 CT_0}{1.2}$

$CT_1 = 0.583 CT_0$

$\boxed{\text{Need to decrease clock rate by 41.7\%}}$

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1.7 [15] <§1.6> Compilers can have a profound impact on the performance of an application. Assume that for a program, compiler A results in a dynamic instruction count of 1.0E9 and has an execution time of 1.1 s, while compiler B results in a dynamic instruction count of 1.2E9 and an execution time of 1.5 s.

a. Find the average CPI for each program given that the processor has a clock cycle time of 1 ns.

b. Assume the compiled programs run on two different processors. If the execution times on the two processors are the same, how much faster is the clock of the processor running compiler A's code versus the clock of the processor running compiler B's code?

c. A new compiler is developed that uses only 6.0E8 instructions and has an average CPI of 1.1. What is the speedup of using this new compiler versus using compiler A or B on the original processor?

a. Compiler A: $1.1s = 1\times10^9 \text{ instr} \times CPI_A \times 10^{-9} \frac{\text{sec}}{\text{cycle}}$

$\boxed{CPI_A = 1.1 \text{ cycles/instr}}$

compiler B: $1.5s = 1.2\times10^9 \text{ instr} \times CPI_B \times 10^{-9} \frac{\text{sec}}{\text{cycle}}$

$\boxed{CPI_B = 1.25 \text{ cycles/instr}}$

b. $ET_A = IC_A \times CPI_A \times CT_A$

$CT_A = \frac{ET_A}{IC_A \times CPI_A}$ $\qquad CT_B = \frac{ET_B}{IC_B \times CPI_B}$

$\frac{CT_A}{CT_B} = \frac{ET_A}{IC_A \times CPI_A} \cdot \frac{IC_B \times CPI_B}{ET_B} = \frac{1.2\times10^9 \times 1.25}{1\times10^9 \times 1.1} = 1.65$

$\boxed{\text{A's processor is 65\% faster}}$

c. $ET_C = IC_C \times CPI_C \times CT_C$
$= 6\times10^8 \times 1.1\times10^{-9}$
$= 6.6\times10^{-1} = 0.66$

$\frac{ET_A}{ET_C} = \frac{1.1}{0.66} = 1.6$

$\frac{ET_B}{ET_C} = \frac{1.5}{0.66} = 2.2$

$\boxed{\begin{array}{l}\text{C is 1.6 times faster than A}\\ \text{C is 2.2 times faster than B}\end{array}}$

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1.13 Another pitfall cited in Section 1.10 is expecting to improve the overall performance of a computer by improving only one aspect of the computer. Consider a computer running a program that requires 250 s, with 70 s spent executing FP instructions, 85 s executed L/S instructions, and 40 s spent executing branch instructions.

1.13.1 [5] <§1.10> By how much is the total time reduced if the time for FP operations is reduced by 20%?

1.13.2 [5] <§1.10> By how much is the time for INT operations reduced if the total time is reduced by 20%?

1.13.3 [5] <§1.10> Can the total time can be reduced by 20% by reducing only the time for branch instructions?

250 - 70 - 85 - 40 = 55

1.13.1 $70(0.2) = 14s$ $\boxed{14 \text{ seconds}}$

1.13.2 $0.8(250) = 200$ => need to decrease by 50 sec $\boxed{\text{Need to reduce INT ops by 50 s or 90\%.}}$

1.13.3 $\frac{40}{250} = 0.16$ If we reduce branch instructions to 0 seconds, we can only decrease the time by a maximum of 40 seconds. This is only a 16% improvement overall so no, we cannot reduce the overall time by 20%.